On the Relative Importance of SO_2 oxidation to High Dust SCR DeNOx units

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Outline

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  - Prediction of SO_3 concentration at SCR outlet
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    - SO_3 capture by fly ash on filter
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  - The fate of SO_3 in coal fired power plants
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- Conclusions

SO_3 formation and related problems

SO_3 formation

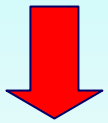
- **Furnace** — **0.7 % of SO_2 conc.**
  - **rule of thumb (US-EPA)**
- **SCR - SO_2 oxidation** — **0.5-1 % of SO_2 conc.**
- **Total** — **1.2-1.7 % of SO_2 conc.**

$$SO_3 + H_2O \not\rightarrow H_2SO_4\ (g)$$

- $\xrightarrow{NH_3}$ NH_4HSO_4 (liq/solid)
- $\xrightarrow{\text{cooling}}$ H_2SO_4 (liq)
- $\xrightarrow{\text{quench}}$ H_2SO_4 (aerosol)

SO_3 capture by fly ash

Less SO_2 oxidation in power plant SCR DeNOx compared to dust free laboratory measurements



$$SO_3 + CaO \rightarrow CaSO_4$$

CaO, MgO, Na_2O, K_2O, Fe_2O_3

Prediction advantages:

- More accurate SO_3 concentrations at the SCR outlet
- Air heater optimization
- Effect of fuel switching or SCR retrofitting

SO_3 capture by fly ash - model

The SO_3 removal rate in the flue gas follows a simple reaction mechanism:

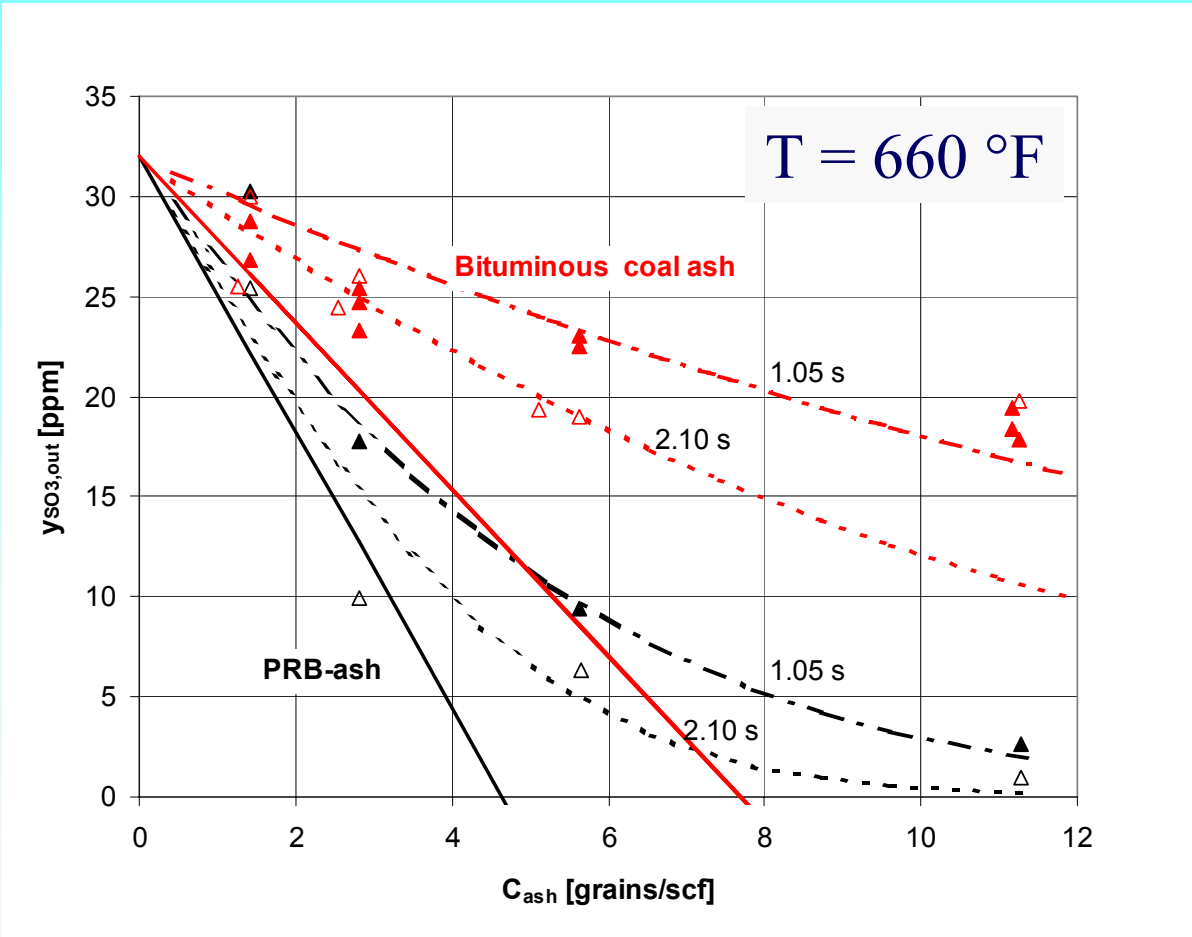
$$-r_{SO_3} = k \cdot C_{SO_3} \cdot C_{CaO}$$

Reaction constant
→ temperature

Gaseous SO_3 concentration

Concentration of alkaline sites
→ ash composition
→ ash concentration
→ particle size distibution

SO_3 capture by fly ash - model



Pilot plant experients

- dust type
- dust loading
- residence time
- temperature
- SO_3 conc.

PRB-ash

- **Alkaline**
- **Fines**

SO_3 measurements

Controlled Condensation Method- a critical review

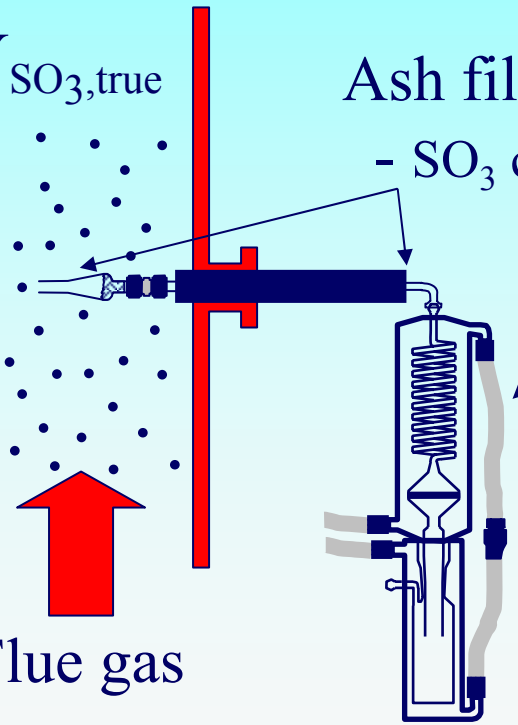
$Y_{SO_3} = ?$

$Y_{SO_3,true}$

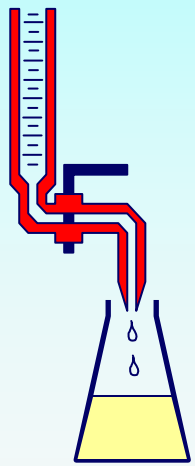
Ash filtration
- SO_3 capture

SO_3 collection
- incomplete collection
  - acid mist
  - rinsing

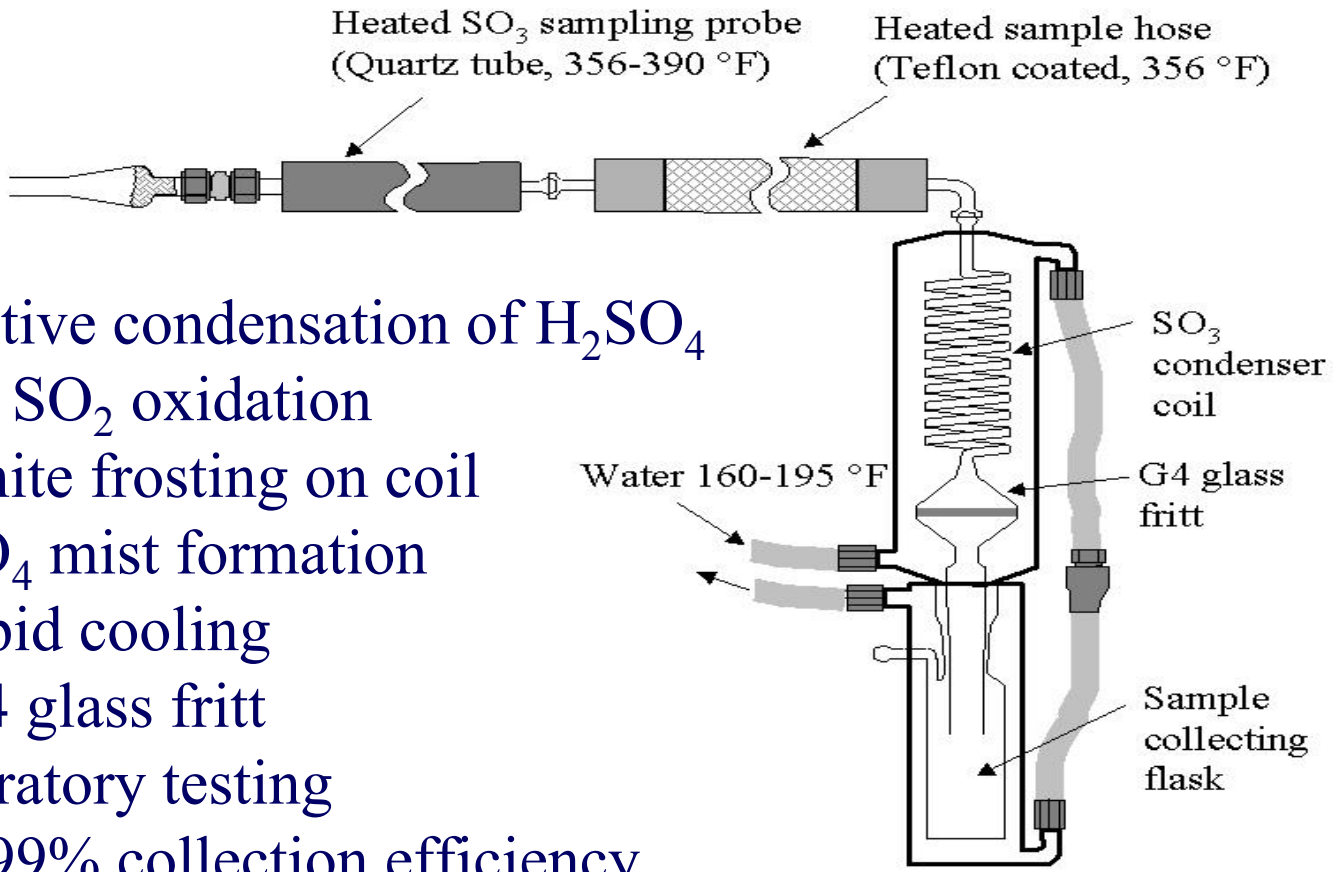
SO_4^{2-} determination
- method of analysis



Flue gas



SO_3 measurements - collection



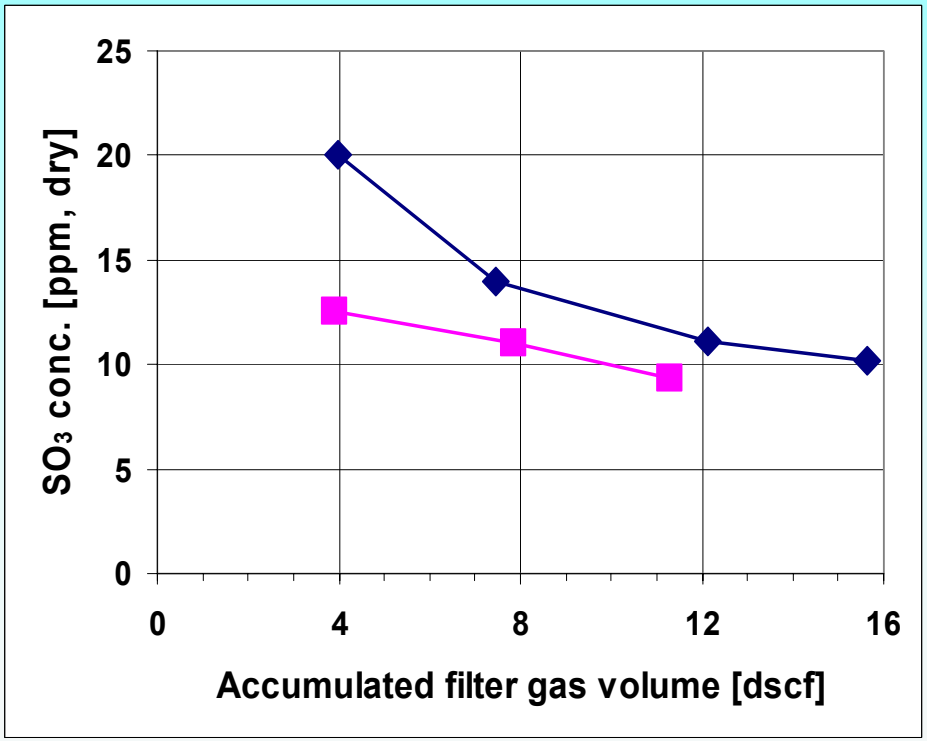
Selective condensation of H_2SO_4
- no SO_2 oxidation
- white frosting on coil

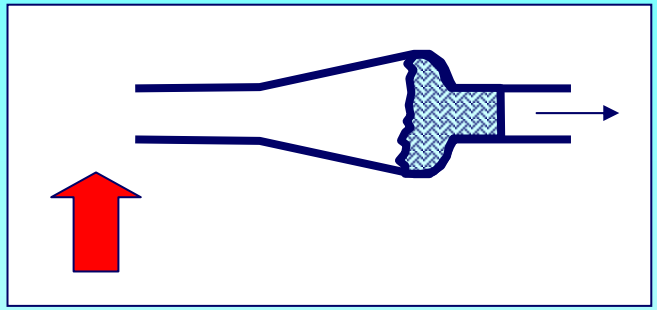
H_2SO_4 mist formation
- rapid cooling
- G4 glass fritt

Laboratory testing
- > 99% collection efficiency

SO_3 measurements - ash filtration

Coal fired power plant
- bituminous coal
- outlet of two SCR's
- 750 °F flue gas



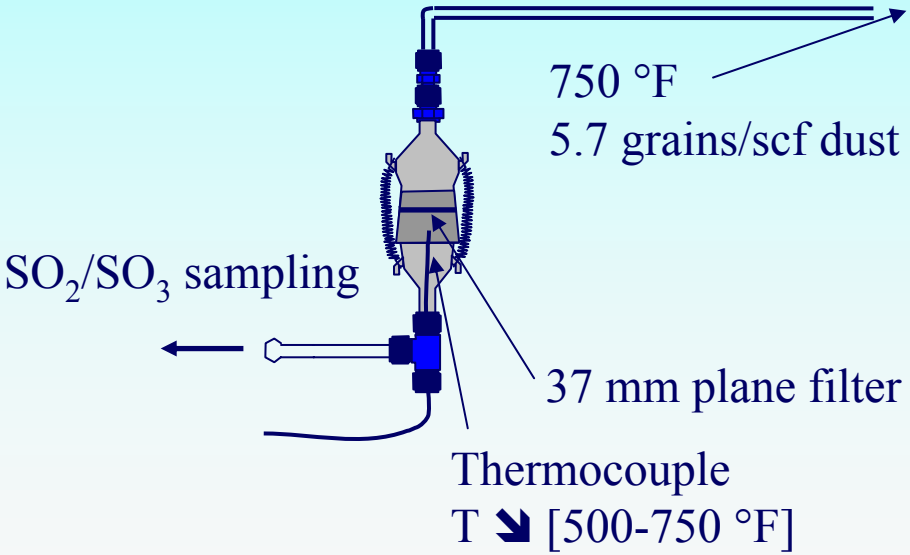


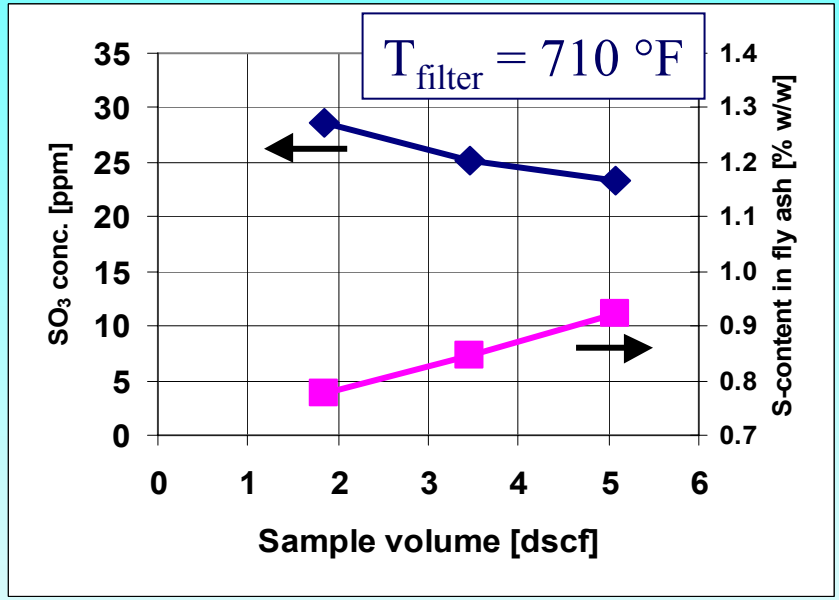
Sampling
- in-duct quartz wool plug
- perpendicular sampling
- re-using filter in consecutive measurements

SO_3 measurements - ash filtration

Pilot plant experiments

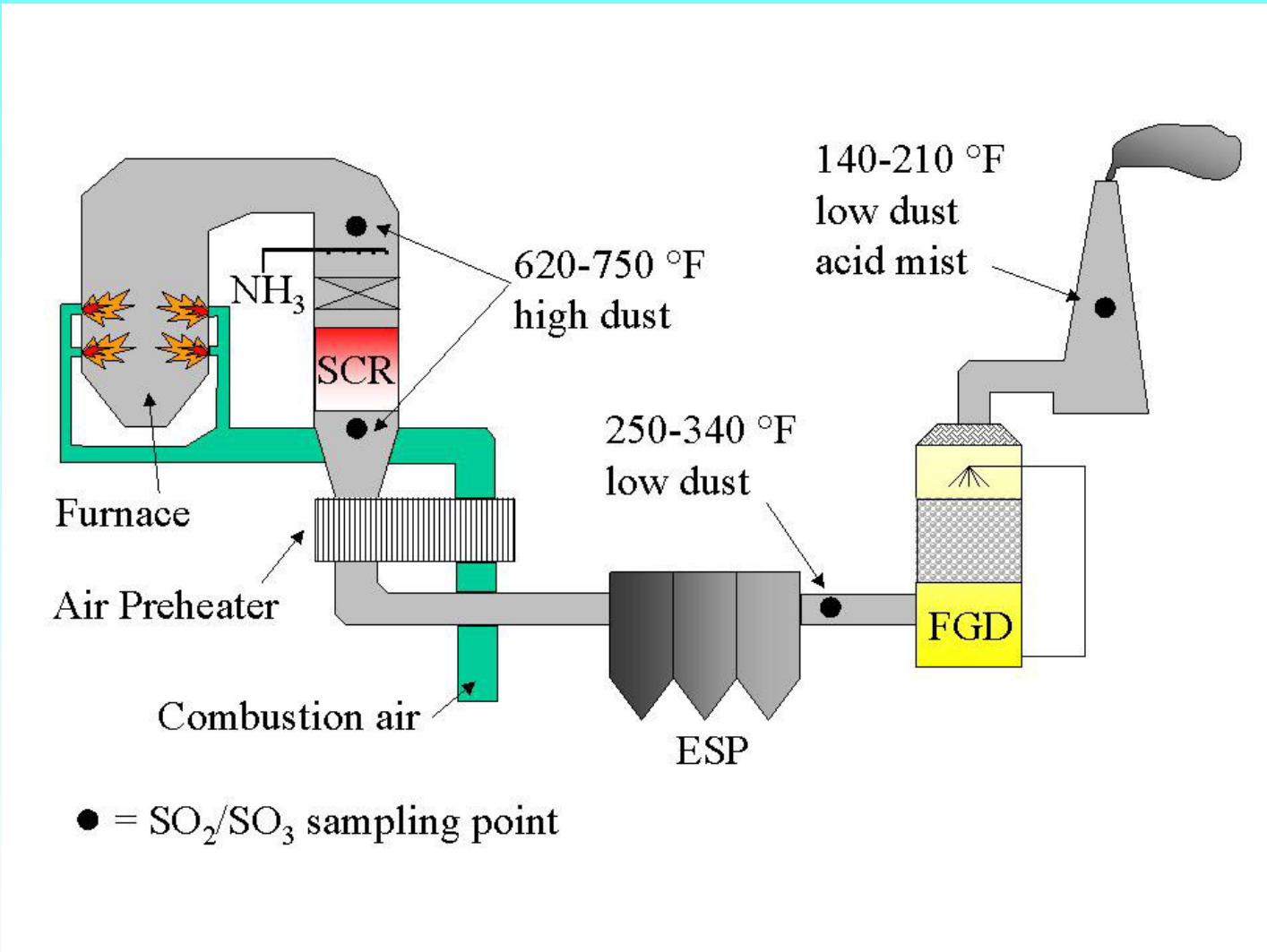
- bituminous coal ash
- 32 ppm SO_3 inlet
- quartz plane filter
  - filter load 2 grains/ft^3





6 ppm SO_3 (~20%) capture per 3.5 dscf sample volume, *independent* on T_{filter}

Case studies - the fate of SO_3



Case studies - power plant data

Harrison power station

- 3 x 640 MW
- high sulfur bituminous coal
- SCR deNOx
- rotary air heater
- cold side ESP
- wet SO_2 scrubber
  - sulfite precipitation

Pleasants power station

- 2 x 625 MW
- high sulfur bituminous coal
- SCR deNOx
- rotary air heater
- cold side ESP
- wet SO_2 scrubber
  - forced oxidation

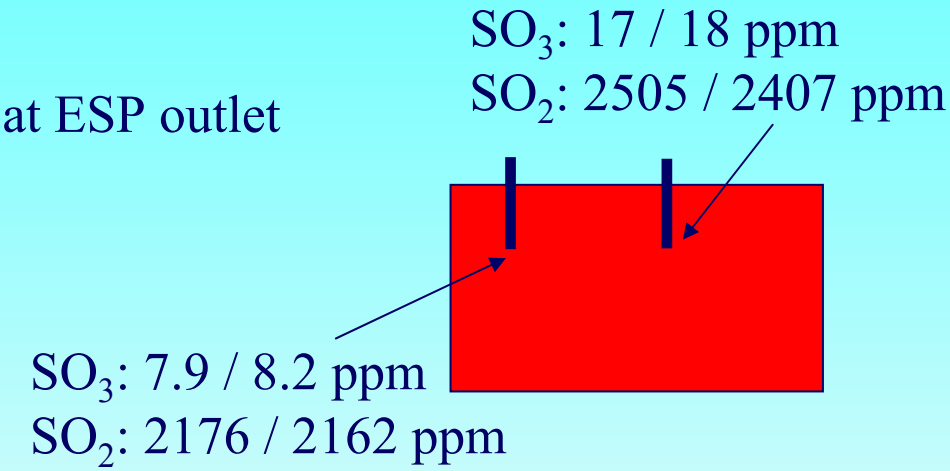
Case stories - results
SCR DeNOx

- Double determinations in three sampling ports
- Four SCR units tested on each power plant
- >12 hour stabilization time
- Static mixers upstream sample ports at Harrison

	Harrison	Pleasants
– SO_2 in	2323 - 2692 ppm	2740 - 3254 ppm
– SO_3 in	26 - 30 ppm	19 - 37 ppm
– inlet stratification		
• SO_2	2.8 - 5.2 %	1.4 - 7.3 %
• SO_3	7 - 15 %	5 - 42 %
– SO_2 out / SO_2 in	0.98 - 1.09	0.96 - 1.01
– *SO_2 oxidation*	*0.29 - 0.81 %*	*0.42 - 0.92 %*
• Temperature	630 - 678 °F	658 - 696 °F

Case stories - results ESP and Stack

- Significant SO_2/SO_3 stratification at ESP outlet
  - → rotary air heater operation
- Some SO_3 removal in FGD



	Harrison	Pleasants
– SO_2 ESP outlet	2313 ppm	2370 ppm
– SO_3 ESP outlet	13 ppm	40 ppm
– stratification		
• SO_2	7.4 %	14 %
• SO_3	46 %	7.5 %
– SO_3 in stack	10 ppm	22 ppm

Conclusions

- SO_3 capture by fly ash reduces observed SO_2 oxidation across SCR DeNOx
  - Prediction by simple reaction mechanism
- SO_3 sampling is not simple
  - SO_3 capture by fly ash on filter
  - Risk of insufficient SO_3 collection
  - Underestimation of true SO_3 concentration
- SO_3 emissions depends on the overall operation of the power plant
  - furnace, SCR deNOx, rotary airheater, ESP and FGD